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Stratification of Particulate and VOC Pollutants in Paint Spray Booths, June 1990

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16. ABSTRACT

The paper discusses flow management as part of a joint EPA/U.S. Air Force program on emissions from paint spray booths. The goal of the program is to identify and develop efficienct and economical emissions control concepts for this source. Flow management is one potential solution that reduces the volume of gases that must be processed in a control system. Although it will not itself control pollution, it can influence the economic and technical viability of subsequent control systems. The test program discussed here was designed to characterize the pollutants both within and exiting a typical back-draw booth for which emissions control and flow management strategies are being developed. Study results indicate that both particulate and volatile organic compounds (VOCs) fall to the lower level of the booth or, at most, stratify at the level at which they were generated. Results indicate that the concentration at the lower level of the booth near the exhaust was from 5 to 25 times greater than that at the upper level. The importance of these findings is that it might be possible to partition a booth's air flow into two zones, one lean and the other concentrated. The enriched lower zone could then be directed to a proportionately smaller VOC control system, of lower capital and operating costs.

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Spray Painting	Stationary Sources	13H
Particles	Paint Booths	14G
Organic Compounds	Particulate	07C
Volatility	Volatile Organic Compounds (VOCs)	20M
Stratification		

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Stratification of Particulate and VOC Pollutants In Paint Spray Booths

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Introduction

The U.S. Environmental Protection Agency (EPA), in a joint program with the U.S. Air Force, has been conducting a research and development test program on emissions from paint spray booths. The goal of the program is to develop emissions control concepts that will permit efficient and economical control of pollutants from paint booths while keeping the booth environment in a safe condition. One approach that addresses the economics of controlling a booth is to reduce the volume of gases from the painting operation that must be processed in a control system. A reduction in flow volume would result in a corresponding reduction of control system capital and operating costs. This test program on an aircraft parts paint spray booth was designed to characterize the pollutant discharges both within and exiting a typical back-draw spray booth for which emissions control and flow reduction strategies are being developed.

The testing program on which the results of this paper are based represents two distinct efforts. The first was to assess the internal booth environment to define the industrial hygiene conditions within the booth, and the second was to define the emission parameters which might govern the operating capability and limitations of a subsequent control technology. This paper presents the results of particulate and Volatile Organic Compound (VOC) concentrations and flow studies of a horizontal flow spray booth. It investigates flow management schemes in this type of booth which take advantage of the natural flow pattern and physical/chemical properties of the generated pollutants. Finally it discusses the implications of the findings in designing economical and efficient booth control strategies resulting from efficient flow management.

The importance of these results in designing booths for efficient flow management is due to the limitations placed upon booth design and operation by The Occupational Safety and Health Administration (OSHA), and The National Fire Protection Association (NFPA). Any design or flow modification of a booth must comply with the codes and regulations established by these organizations.

Test Strategy and Site Description

The objectives of the experiments were to determine how and where pollutants passed through and from the booth and the areas of highest concentration. The sampling scheme devised allowed development of a three dimensional representation of the concentration profile in the booth during painting. Thus, it was possible to observe how concentrations varied along the length of the booth and at different heights in the booth. The graphical representation developed allowed observation of the degree to which the flow and concentration profile complies with the applicable spray booth codes.

The test site was a horizontal flow back-draw spray booth with air flowing from the front to the rear of the booth and exiting through a particulate removal water curtain. Figure 1 describes the general configuration and dimensions of the booth. A maximum of two painters were present in the booth during testing. The measured flow rate through the booth ranged between 11,000 and 11,500 SCFM (5.2 and 5.4 m^3/s) with an average velocity of 100 ft/min (30.49 m/min).

The booth was instrumented with National Institute for Occupational Safety and Health (NIOSH) personal samplers positioned to form an approximate three dimensional grid matrix scheme inside the paint booth. The sampling instruments were positioned in the booth to define the average particulate concentrations experienced by each respective grid section during the test episode. Figure 2 illustrates the top and side views of the instrument locations in the booth. A total of 21 grid points were located in the booth. Measurements also were taken in the spray booth duct and at the painters' breathing zone to define duct and breathing zone particulate concentrations relative to the general booth interior. Particulate concentrations in the duct were determined using EPA Method 5 emissions sampling procedures. Three tests were performed to determine particulate concentration profiles in the booth using the NIOSH 500 sampling protocol.

Two tests were performed to define average VOC concentrations within the booth. The same grid scheme and sampling locations were used as described for the particulate tests. These experiments were conducted in accordance with the NIOSH 1300 procedure, using personal sampling instruments. Duct VOC measurements were taken using EPA Method 25 and Bay Area Air Quality Management District (BAAQMD) Method ST-7. Each painting episode and sample collection experiment lasted approximately 40 minutes.

Items painted during the experiments were general aircraft ground equipment of various sizes and shapes ranging up to approximately 8 ft (2.4 m) in height. They were selected to represent a range of items typically painted in a spray booth.

Results

Evaluations of both particulate and VOC emissions were made. The results of these evaluations are presented below.

Particulate:

The results of the particulate experiments indicate that the average paint particle concentration measurements tend to stratify at approximately the vertical height at which the particles were generated. To show this phenomenon the concentration values at each respective height and length along the width of the booth were plotted logarithmically for each test. This permitted a determination of the average concentration along the length of the booth for the horizontal plane defined by the grid sections of that plane. Figures 3, 4, and 5, developed from each test, respectively, are an average of those values. The plotted points represent the average concentration along the length of the booth for height ranges of 0-5 and 6-12 ft (0-1.5 and 1.8-3.7 m). These figures indicate two distinct concentration regions: one established by the painting operation, and the other relatively unaffected by painting within the booth. As shown in the figures, the particulate loading in the lower portion of the booth tended to increase as the pollutant moved toward the exit of the booth, or at most remained in the same relative proportion at the exit as that established during painting. The concentration measurements at or near the exit of the booth were from 40 to 95 percent greater than those observed in the upper region of the booth.

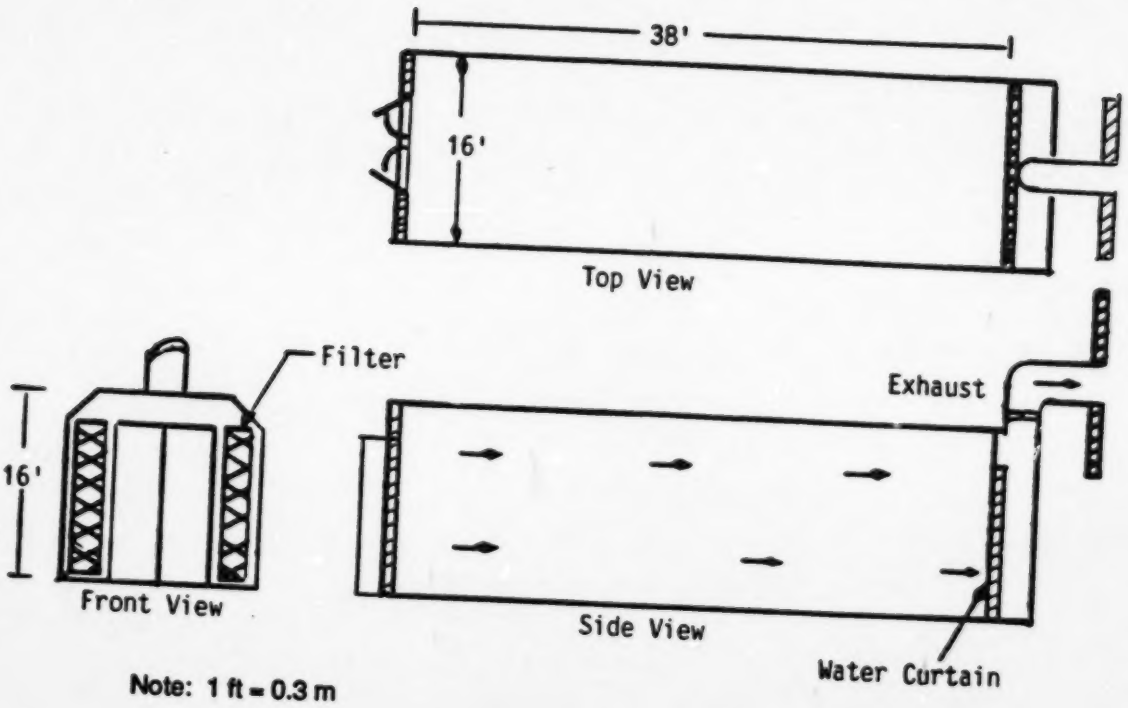

Figure 1. Spray booth diagram.

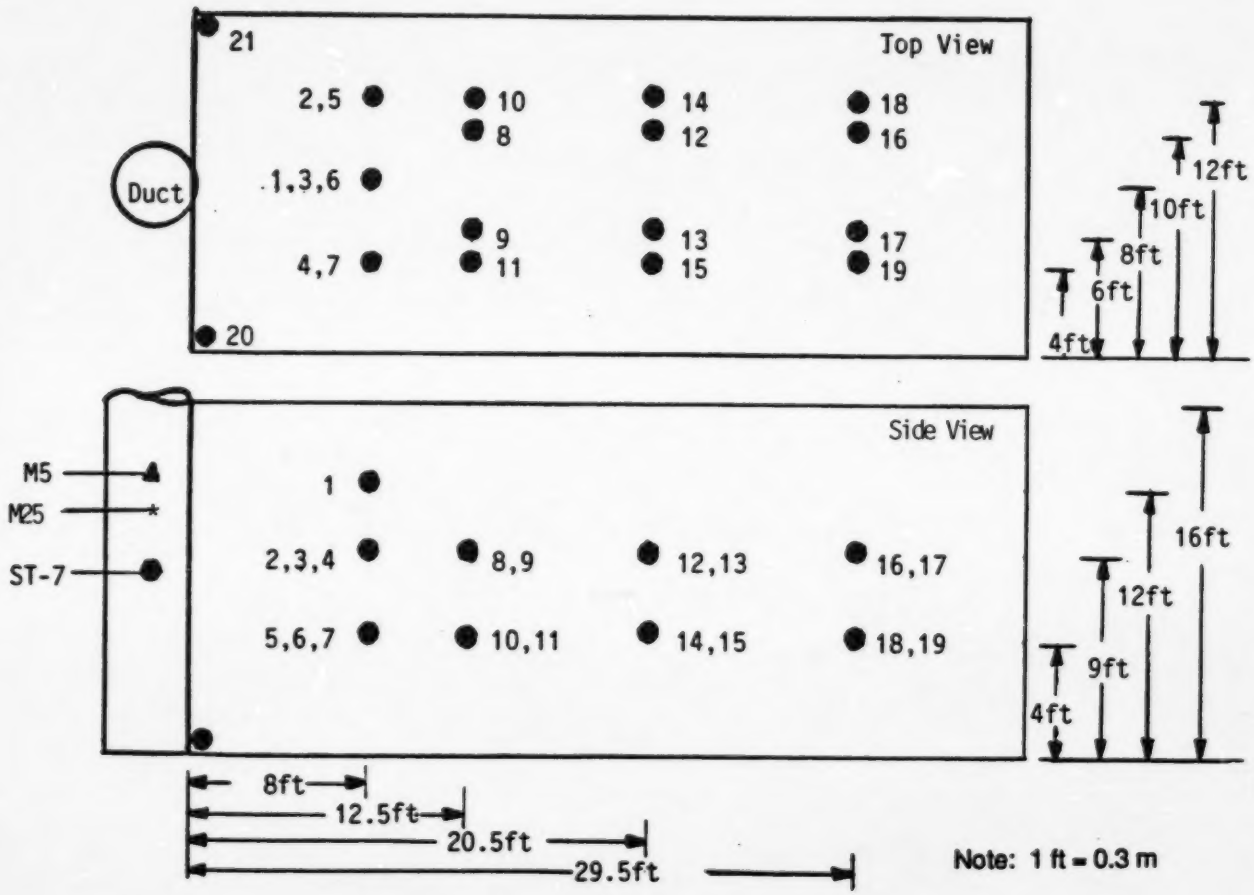

Figure 2. Booth sampling locations.

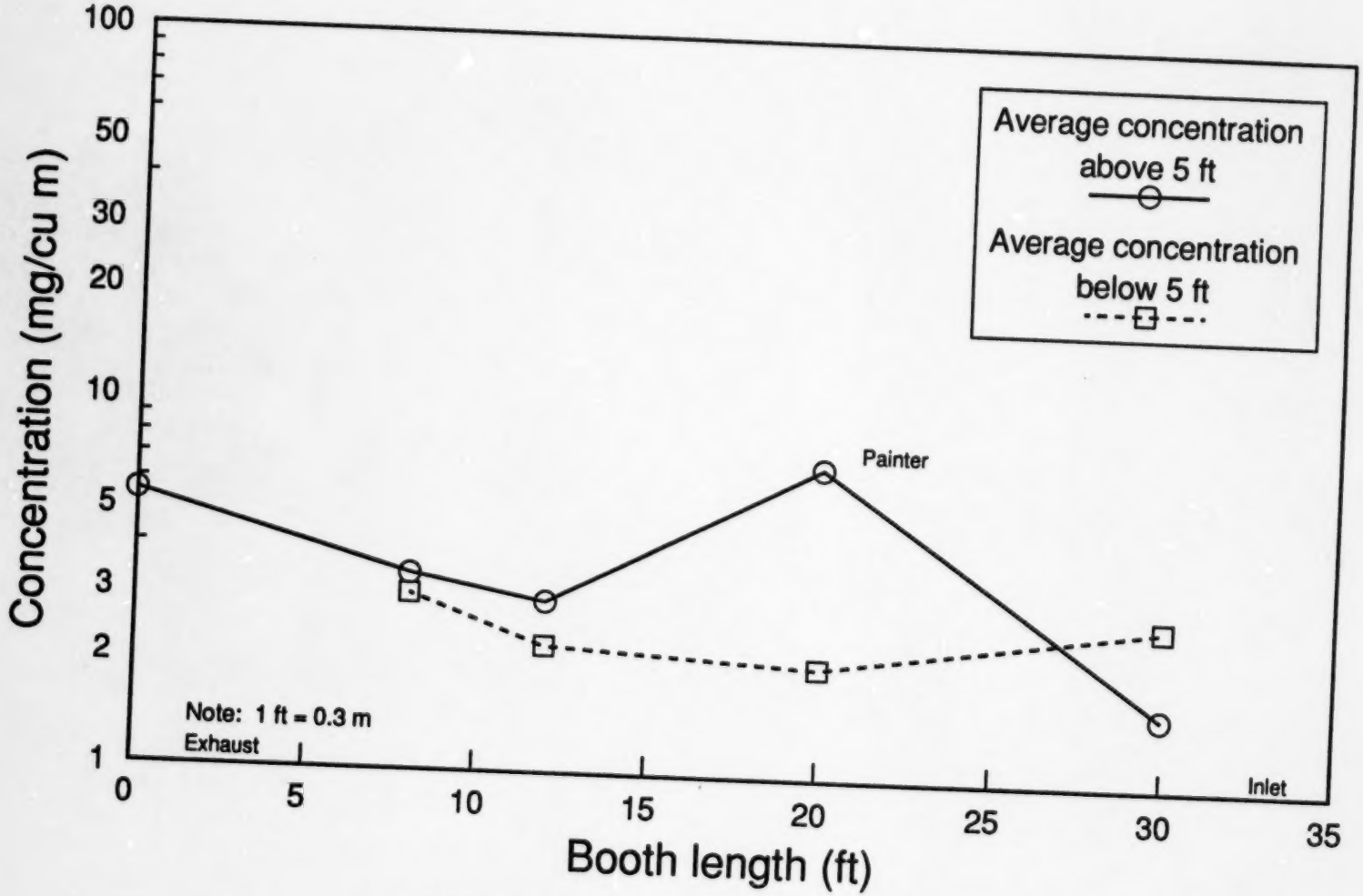

Figure 3. Average particulate concentration along length of test booth, particulate test 1.

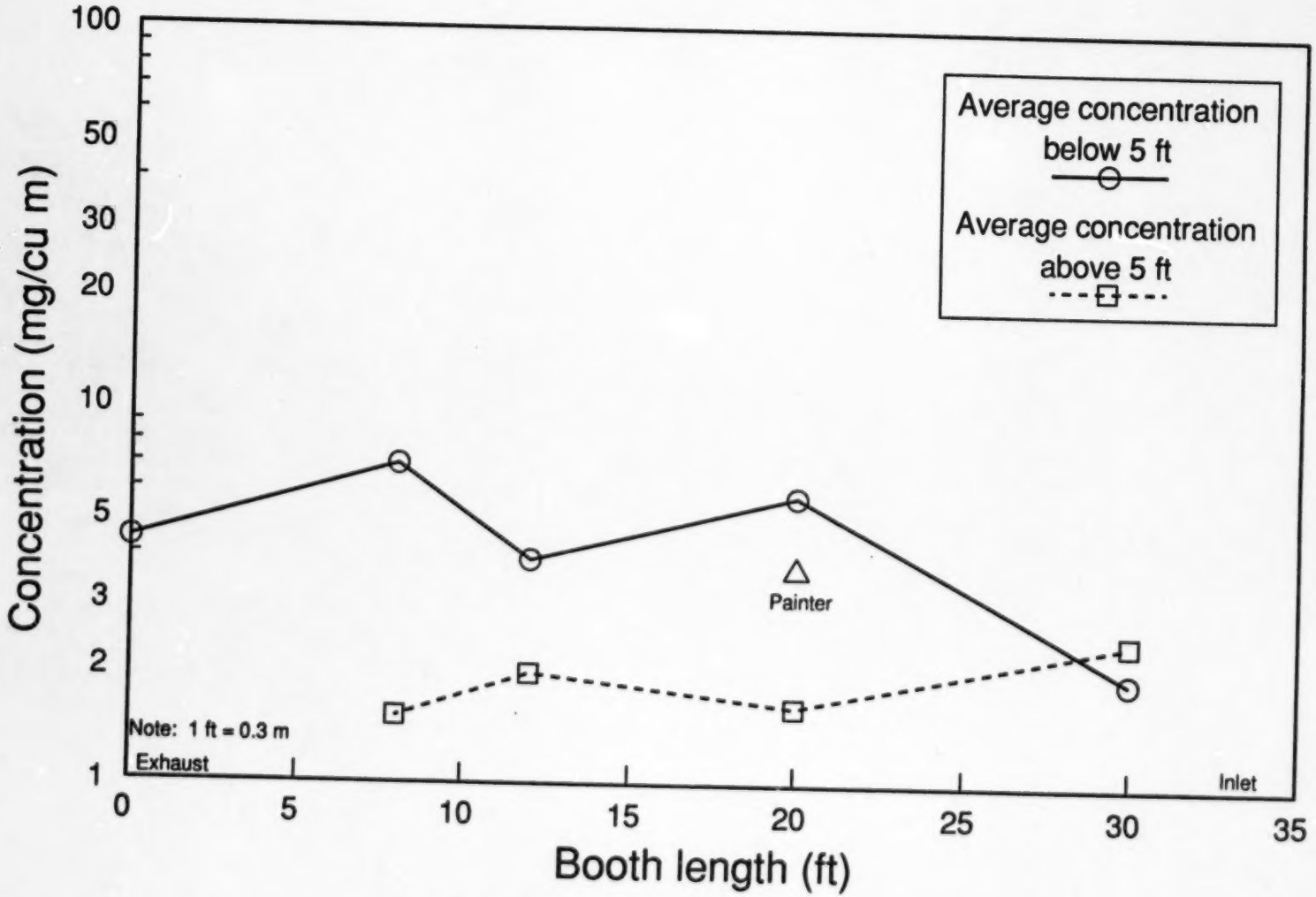

Figure 4. Average particulate concentration along length of test booth, particulate test 2.

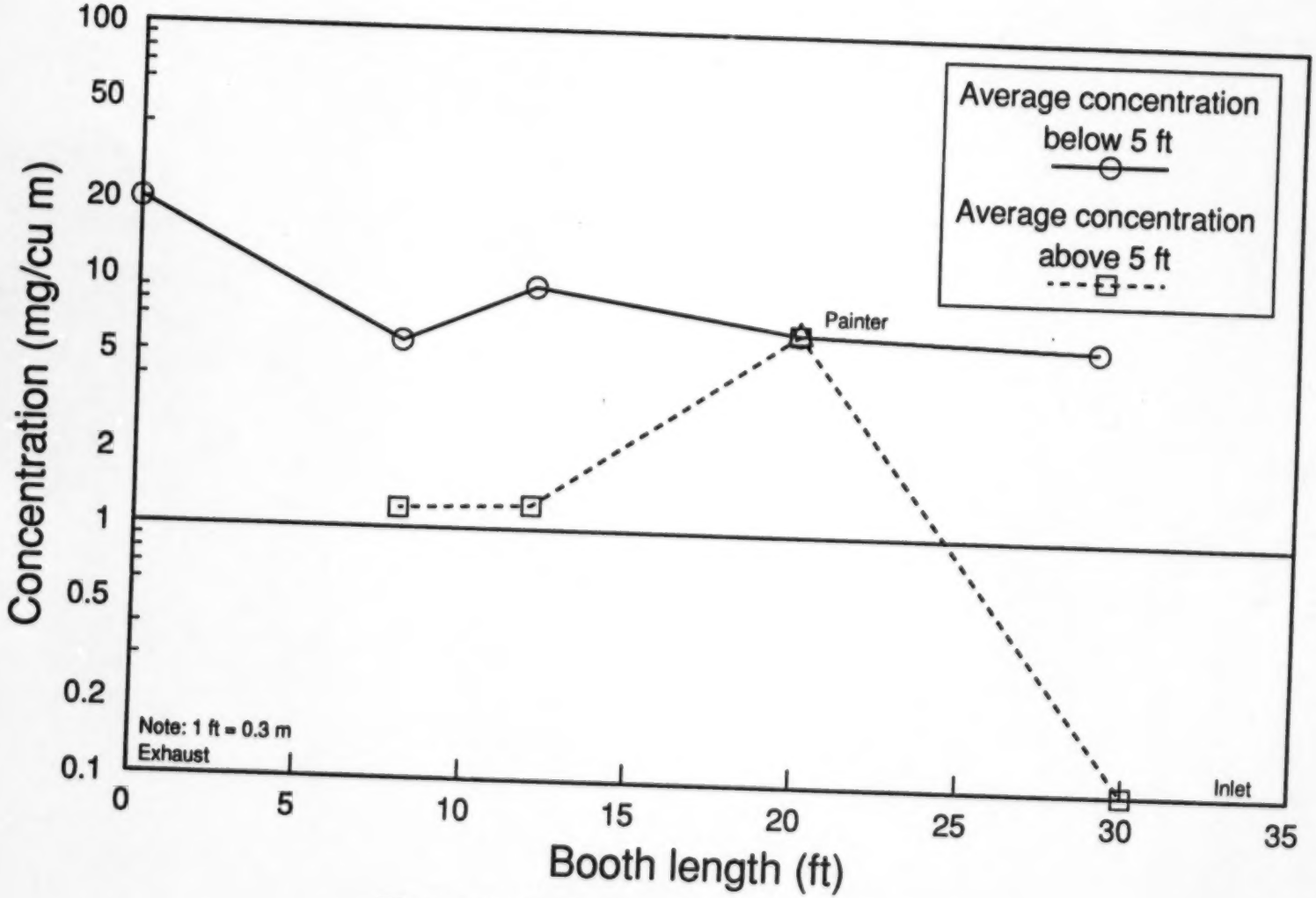

Figure 5. Average particulate concentration along length of test booth, particulate test 3.

Volatiles (VOC):

The VOC sampling utilized the same instrumentation and locations described for the particulate experiments. The VOC results indicated a more pronounced separation of the concentration ranges than those defined for particulates. The VOC concentration profiles clearly tend to decrease in the upper level of the booth and correspondingly increase in the lower level of the booth as the downstream distance from the painting zone increases. Figures 6 and 7 present the results of those experiments. In Figure 6, the average concentration in the upper portion of the booth was measured at 8 ug/l, or 3 percent of the average concentration, 271 ug/l, measured in the lower portion of the booth. Similarly, in Figure 7, the concentration in the upper portion of the booth was observed to be 22 ug/l, or 20 percent of the lower booth concentration, 108 ug/l. In both cases the concentration of volatiles in the lower portion of the booth tends to increase as the pollutant proceeds to the exhaust end of the booth.

Conclusions

The finding that the average concentration at the higher levels of the booth is typically lower and tends to decrease as the distance from the painting zone increases must be considered significant in the design of horizontal flow spray booths. The painting zone was located between 10 and 25 ft (3.0 and 7.6 m) from the discharge end of the booth. Yet, the results indicated that the particulate or paint overspray did not rise from the general level of paint application which would have resulted in equalization of concentration at all levels of the booth downstream from the painting zone. Little vertical mixing of the pollutants was apparent. More importantly the results indicate that the greatest mass of the particulate falls to and concentrates at the lower level of the booth as it proceeds to the exit. As confirmed by the results, it would be expected intuitively that the particulate matter would fall since it is heavier than air. Conventional booth design, however, seems to assume that the pollutant establishes an equilibrium in the booth which would result in approximately the same concentration at all downstream levels of the booth.

Similarly and equally important is the lack of dispersion of VOCs in the booth. Similar to the particulate trend, the VOC concentration tended to increase as it approached the lower booth exhaust area. However, the degree of concentration is indicated to be even greater, with as much as 80 percent of the generated VOC exhausting from the lower portion of the booth.

These findings indicate a possible approach to enhance the effort to reduce the cost of controlling pollution from paint spray booths. First, since the particulate tends to fall as it progresses from the point of generation, by increasing the distance from the primary painting area to the exhaust, a significant portion of the particulate could be expected to fall to the lower level of the booth. A similar scenario can also be envisioned for VOCs, but with greater efficiency. The results indicate that the partitioning of the booth into two discharge zones might be an approach to reduce the volume of pollutant laden discharge that requires pollution control. One discharge, the lean stream from the upper region of the booth, might be directed to the atmosphere or recirculated back to the booth via a particulate control system. The second stream, the pollutant rich discharge which contains the greatest volume of volatile pollutants, can be directed to a VOC control system. This would result in a significant reduction of the volume of exhaust that must be directed to a pollution control system. Partitioning the booth exhaust into two exhaust streams will not alter the operating characteristics of the booth. The booth can be operated within all of the safety and operating code requirements which govern flow volumes and velocities within spray booths. Assuming that the flow in the booth is approximately laminar, it is estimated that a minimum of 50 percent reduction of exhaust flow to the control system can be achieved by partitioning, yet permitting the capture of

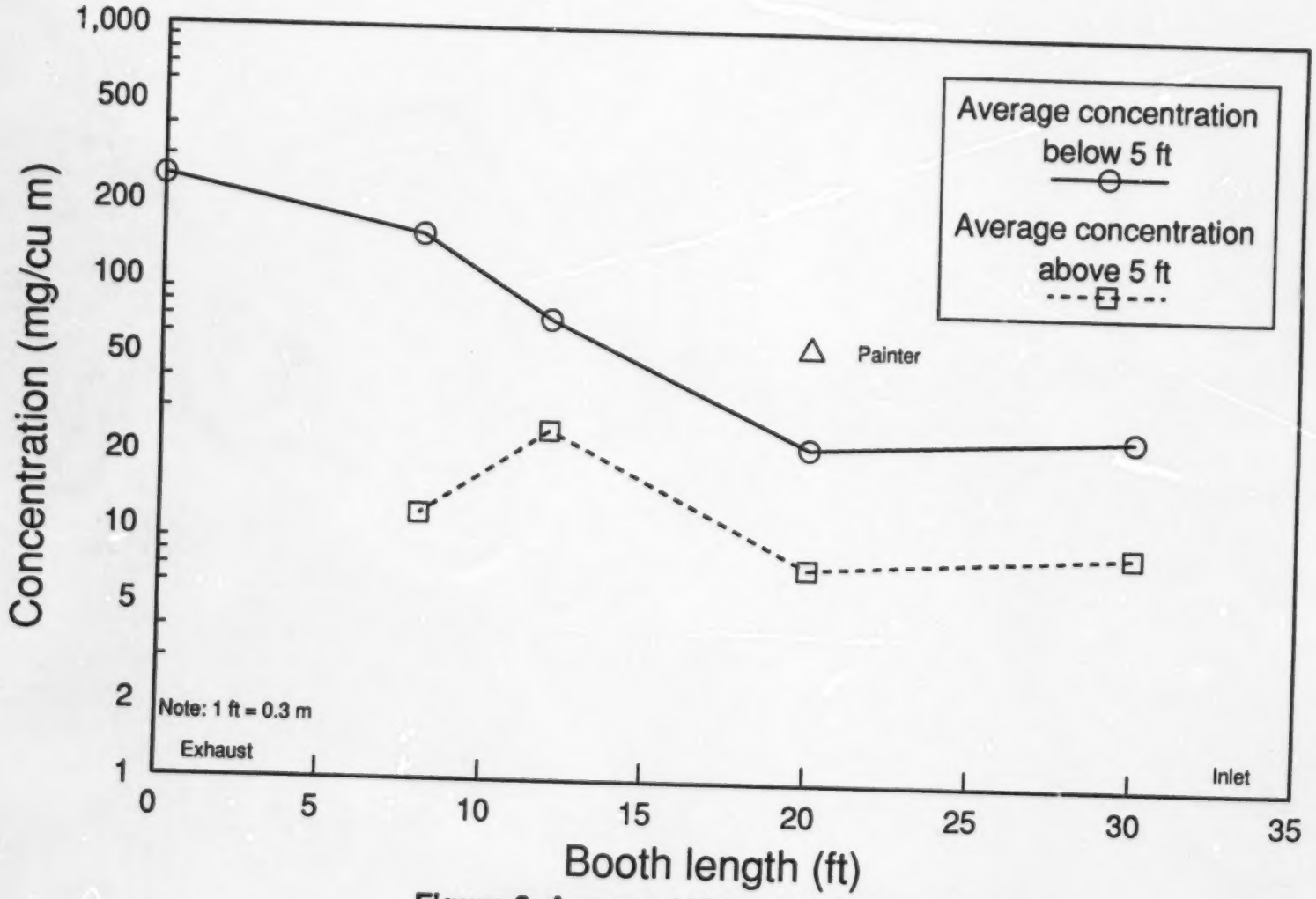

Figure 6. Average VOC concentration along length of test booth: VOC test 1.

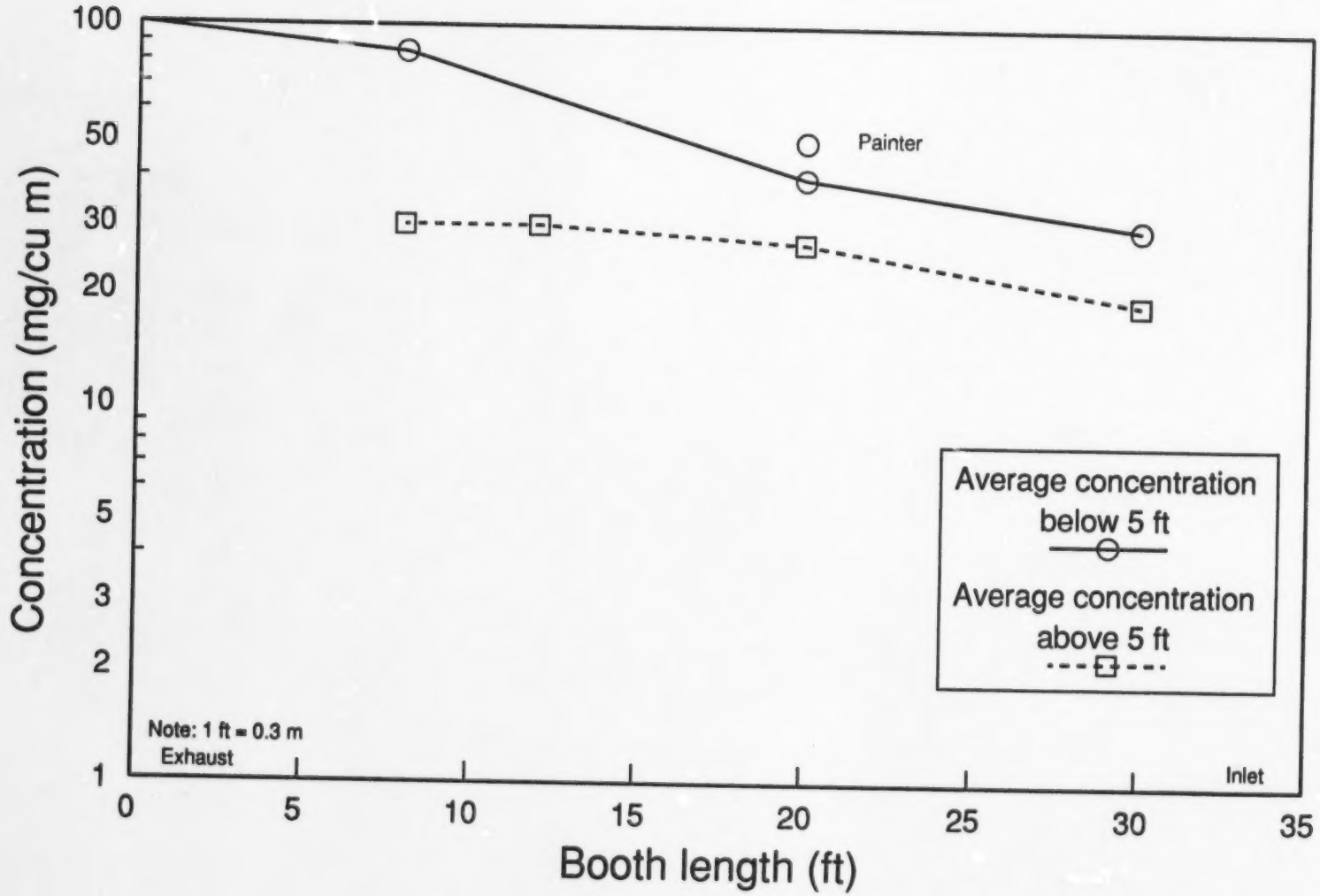

Figure 7. Average VOC concentration along length of test booth: VOC test 2.

up to 80 percent of the booth exhaust pollutants. If feasible this scenario could result in a reduction in capital and operating cost for the control system since the total volume of gas that would require processing could be reduced compared to an unpartitioned booth.

At present the research results suggest only a possible concept for reducing the capital and operating costs for spray booth emissions control by reducing the volume flow rate of emissions that must be treated . At the very least the data tend to indicate that a significant portion of the process pollutants can be collected from a relatively small volume of the total booth air flow.